Chapter 7

Conclusions

In this final chapter we summarize some of the important observations of the thesis, the deductions we draw from them and their significance with respect to other experimental and theoretical work In the first chapter we had pointed out some interesting aspects of the different experimental observations in this class of manganites We present the conclusions with regard to those questions We also give an outline for future work, taking the present set of investigation to a better conclusion

- Point contact spectroscopy was used to estimate the EPI function on a SC of $La_{0\ 75}Sr_{0\ 25}MnO_3$ The EPI function obtained shows the presence of optical phonon modes, in the energy interval 20 - 80 meV The phonon modes are identified with the different modes of vibration of the MnO_6 octahedra and La-MNO_3 obtained from different experimental investigations and theoretical calculations The EPI function is strongest in the energy range 40 - 60 meV, corresponding to the O-Mn-O chain vibrations This is an important observation since that charge transport in these systems takes place by carrier hopping along the O-M-O chain and thus are affected by the phononic modes arising out of their vibrations

  The results also indicate a large electron-phonon coupling constant $\lambda \sim 1\ 2$ Using the EPI function we were able to calculate the phononic contribution to resistivity in the system It shows a good match to the experimentally obtained resistivity below 100 K This novel result establishes a phononic origin of the resistivity in the FM phase of the manganites, in a regime where MR is almost negligible and the spin-disorder scattering is negligible The result also puts an estimate on the spin-disorder contribution of the resistivity, dominant at higher temperatures Thus we were able to explain the low temperature resistivity of the system as arising out of optical phonons present in the system

- The barrier tunneling spectroscopy on SCs of $La_{0\ 75}Sr_{0\ 25}MnO_3$ and $La_{0\ 7}Ca_{0\ 3}MnO_3$ clearly shows the presence of a depletion in the sample DOS at E_F, at 4 2 K This low energy ($|\epsilon| \leq 15$ meV) feature observed at 4 2 K indicate that carrier localisation effects are present in the system even though the transport measurements indicate a metallic behaviour Such a depletion in DOS, though very shallow is unconventional in a metallic system These low energy features are not observed at higher temperatures primarily due to thermal smearing
  Interestingly we also observe that the depletion in the DOS for the wider band gap $La_{0\ 75}Sr_{0\ 25}MnO_3$ is shallower than that for $La_{0\ 7}Ca_{0\ 3}MnO_3$ This observation is indeed important and requires further experimental investigations and theoretical work to explain the observation Although the conclusive is sill lacking, it is reasonable to expect that this depression is related to the larger depressions in the DOS observed near the T_c of these manganites

- The STM based vacuum tunneling studies carried out on 50 nm thin film of $La_{0\ 7}Ca_{0\ 3}MnO_3$ explores the variation of DOS near T_c of the system The STS studies on the strain free film (exhibiting little or no PS) clearly bears signature of the metal insulator transition at T_c The energy dependence of the DOS close to E_F is seen to change quantitatively across the T_c The zero bias tunnel conductance, which is also representative of $N_s(E_F)$ shows a large decrease near T_c, reflecting the large increase in resistivity observed Interestingly the energy dependence of the DOS near E_F, in the metallic state, is similar to that seen in other correlated oxides with disorder
  Above T_c we observe a finite DOS at E_F contrary to the expected gapped DOS Simulations of conductance data above T_c indicate that the finite temperature effects might be responsible for the high zero bias conductance and the finite DOS at E_F We infer, the sharp rise in ρ on approaching T_c from the metallic side appears to be determined by a depression in the DOS at E_F

- The spatially resolved spectroscopic (CMAP) studies on thin films of $La_{0\ 7}Ca_{0\ 3}MnO_3$

with varying degree of strain, explored the role of film-substrate mismatch induced biaxial strain in causing phase separation in the FM metallic phase The transport measurements and the CMAP studies on the strained and unstrained films show markedly different behaviour We observe that the strained films are phase separated while the unstrained one shows no detectable phase separation We also observe that with decrease of T, below T_c, not only the fraction of metallic phases increase, but the average conductivity of both the high conductance as well as the low conductance phases increase

The presence of phase separation was further confirmed by the high electrical noise observed in the strained film compared to the unstrained one We infer that phase separation is neither an intrinsic property of the manganites nor essential to explain the MIT seen in these samples Rather the strong electron-lattice coupling in the system causes phase separation due to lattice distortions caused by the strain in the sample

Scope for future investigations:

The large change in resistivity at T_c in these manganites have been indicated to arise from the large change in the DOS near T_c However, it says nothing about the magnetic response of the DOS at T_c We need to carry out similar STS measurements as a function of magnetic field to see whether the colossal magnetoresistance effect is reflected in the change of DOS with magnetic field

The observation of phase separation as a function of temperature will be further strengthened in case we observe similar behaviour as a function of magnetic field The temperature dependent CMAPs show that the volume fraction and the conductance of the higher conducting phases increases with decrease of temperature It would be rather interesting to see the effect of magnetic field Do the volume fraction as well as the magnitude of conductance of the phases change with field?

Of particular importance will be a CMAP study on a *high quality* single crystal sample Only when we observe no PS in that system will we be able to settle the role of strain in the PS phenomena

We have pointed out certain differences between the PS picture as investigated by the CMAP and electrical noise measurements Probably the best way to see whether the domains fluctuate with time is to study the noise in the tunnel current or the fluctuations in tunneling conductance directly One can position the tip over a phase separated domain and record the time series This would be the ideal technique to probe the question of noise arising from domain fluctuations Again, such studies carried out at different magnetic fields would give us invaluable information

One must appreciate that the above studies outlined are rather difficult experiments Our investigations and published literature shows the extent to which the substrate affects the thin film properties Keeping both the above limitations in mind a highly meticulous STM based study is required to settle the issue of PS and if possible on a single crystal sample